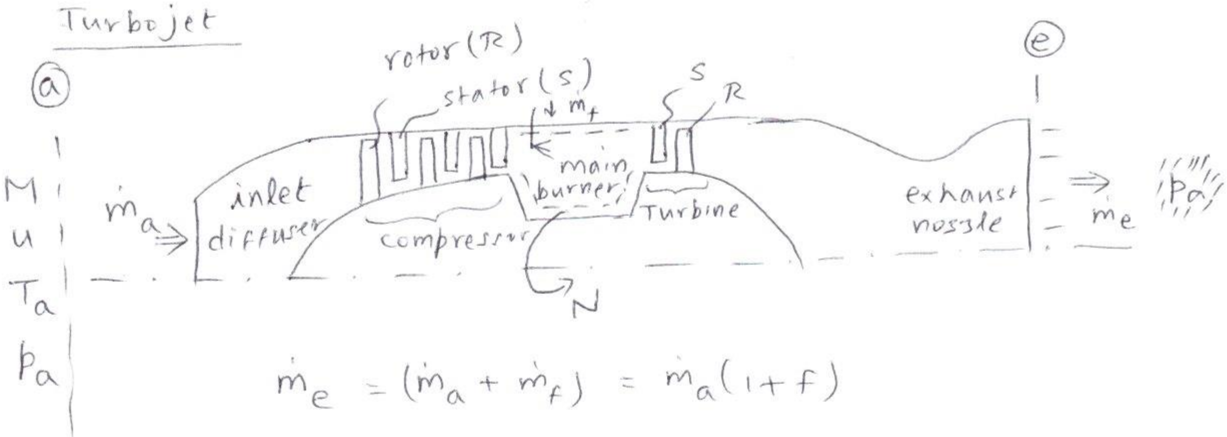
Turbojet



free stream

$$\dot m_e = (\dot m_a + \dot m_f) = \dot m_a (1+f)$$

$$T = \dot m_a (1+f) u_e - \dot m_a u + (p_e - p_a) A_e$$

$$TSFC = \frac{\dot m_f}{T}, \quad (TSFC)_{wb} = (TSFC)\, g_e$$

Ex: $\dot m_a = 100$ kg/s, $u = 240$ m/s, $u_e = 890$ m/s, $f = 0.02$, fully expanded exhaust jet. Find T and $(TSFC)_{wb}$

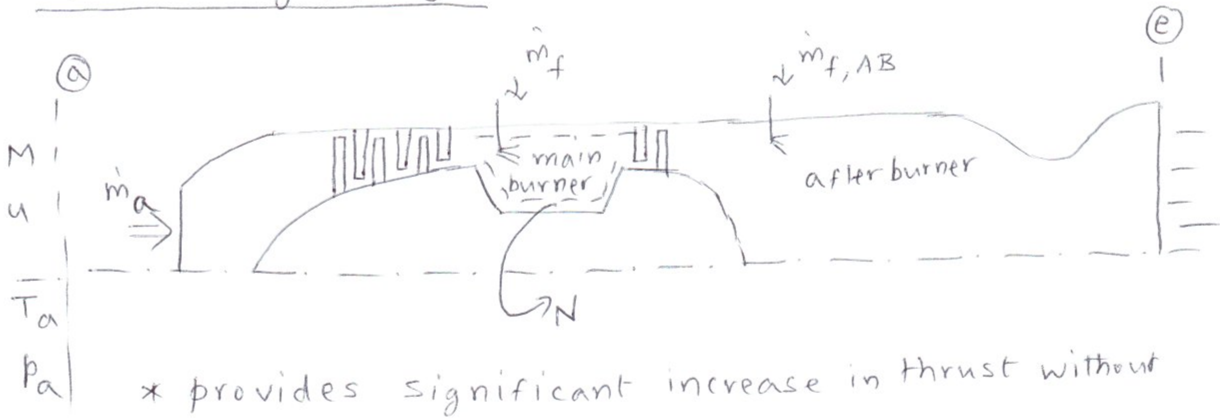
$$T = \dot m_a (1+f) u_e - \dot m_a u + \underbrace{\cancel{(p_e - p_a)}}_{0 \text{ [fully expanded; } p_e = p_a]} A_e$$

$$= 100(1+0.02)890 - (100)(240) = 66780 \text{ N}$$

$$(TSFC)_{wb} = \frac{\dot w_f}{T} = \frac{\dot m_f g_e}{T} = \frac{f \dot m_a g_e}{T} = \frac{(0.02)(100)(9.81)}{66780}$$

$$= 2.938(10^{-4}) \frac{1}{s} \underset{\times 3600}{=} 1.058 \text{ h}^{-1}$$

Afterburning turbojet

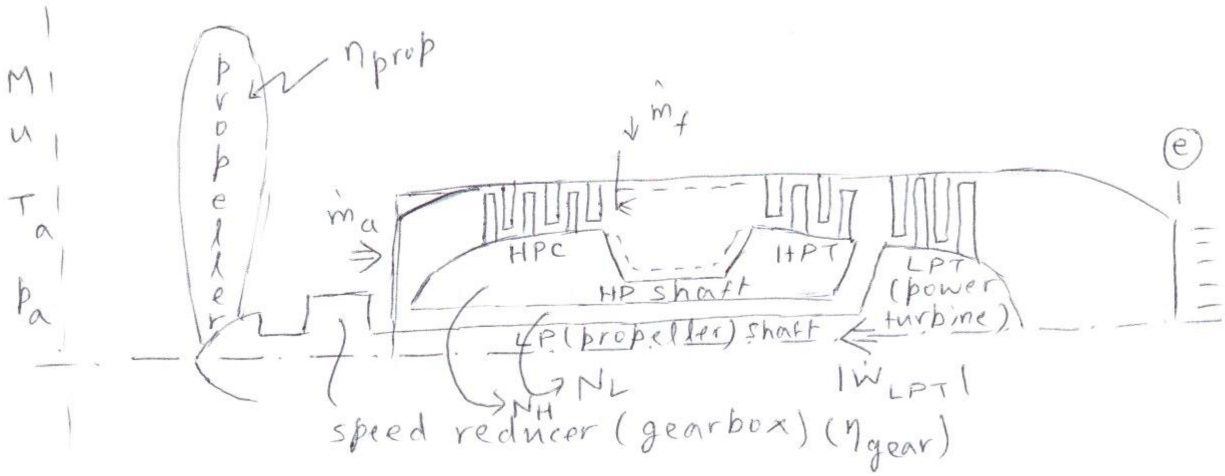


* provides significant increase in thrust without sizable increase in engine weight

* burns hotter and has lower efficiency than its non-afterburning counterpart.

$$T = (\dot{m}_a + \dot{m}_f + \dot{m}_{f,AB})\, u_e - \dot{m}_a u + (p_e - p_a) A_e$$

$$(TSFC)_{wb} = \frac{(\dot{m}_f + \dot{m}_{f,AB})\, g_e}{T}$$



a

η_{gear} – gearbox power transmission efficiency

η_{prop} – propeller " "

$$|\dot{W}_{prop}| = \eta_{prop}\eta_{gear}\eta_m |\dot{W}_{LPT}|$$

η_m – shaft mechanical power transmission efficiency

$$T_{prop} = \frac{|\dot{W}_{prop}|}{u}$$

$$T_{noz} = \dot{m}_a(1+f)u_e - \dot{m}_a u + \overset{\text{zero}}{\cancel{(p_e - p_a)}}A_e$$

$$T = T_{prop} + T_{noz}$$

$$(TSFC)_{wb} = \frac{\dot{m}_f g_e}{T} = \frac{\dot{m}_f g_e}{T_{prop} + T_{noz}}$$

$$EBSFC = \frac{\dot{m}_f g_e}{Tu} = \frac{(TSFC)_{wb}}{u} = \frac{\dot{m}_f g_e}{(|\dot{W}_{LPT}|\eta_{prop}\eta_{gear}\eta_m + T_{noz}u)}$$

N/s

W $\Rightarrow \frac{N}{W\text{-}s}$ (or) $\frac{N}{kWh}$

Ex: A turboprop engine has the following characteristics:

$u = 200$ m/s, $\dot{m}_a = 70$ kg/s, $|\dot{W}_{LPT}| = 24$ MW,

$\eta_{gear} = 0.95$, $\eta_{prop} = 0.78$, $\eta_m = 0.99$, $u_e = 400$ m/s,

$f = 0.02$, fully expanded exhaust jet.

Find $\dot{m}_f$, T_{noz}, T_{prop}, T, $(TSFC)_{wb}$, EBSFC and % of thrust generated by the propeller.

$$\dot{m}_f = f\dot{m}_a = (0.02)(70) = 1.4 \text{ kg/s} \underset{\otimes 3600}{=} 5040 \text{ kg/h}$$

$$T_{noz} = \dot{m}_a(1+f)u_e - \dot{m}_a u + \overset{\nearrow 0\ (p_e = p_a,\ \text{fully expanded jet})}{\cancel{(p_e - p_a)A_e}}$$

$$= 70(1+0.02)(400) - (70)(200) + 0 = 14560 \text{ N}$$

$$|\dot{W}_{prop}| = \eta_{prop}\eta_{gear}\eta_m|\dot{W}_{LPT}| = (0.78)(0.95)(0.99)(24)$$

$$= 17.61 \text{ MW}$$

$$T_{prop} = \frac{|\dot{W}_{prop}|}{u} = \frac{(17.61)(10^6)}{200}$$

$$= 88050 \text{ N}$$

$$T = T_{noz} + T_{prop} = 14560 + 88050 = 102610 \text{ N}$$

$$(TSFC)_{wb} = \frac{\dot{m}_f g_e}{T} = \frac{(1.4)(9.81)}{102610} = 1.3385(10^{-4})\ \frac{1}{s}$$

$$\underset{\times 3600}{=} 0.482 \text{ h}^{-1}$$

$$EBSFC = \frac{(TSFC)_{wb}}{u} = \frac{1.3385(10^{-4})}{200} = 6.6925(10^{-7})\ \frac{1}{m}$$

$$= 6.6925(10^{-7})\frac{N}{W\text{-}s} \underset{\otimes 3600 \times 1000}{=} 2.41 \frac{N}{kWh}$$

% of thrust generated by the propeller $= \left(\frac{88050}{102610}\right)100 = 85.8\%$